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A Comparison of Direct Survival/Injury of Eels Passed Through Francis and Propeller Turbines

Paul G. Heisey
Normandeau Associates, Inc.

Dilip Mathur
Normandeau Associates, Inc.

J. Christopher Avalos
Normandeau Associates, Inc.

Cory E. Hoffman
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Introduction

- Stocks of catadromous American *Anguilla rostrata* and European *A. anguilla* Eels have declined over the last several decades.
- Among a host of factors cited for these declines, mortality resulting from downstream passage through turbines at hydroelectric facilities has been of concern.
- Estimates of immediate (direct effects) passage mortality can be obtained with relatively high precision using the HI-Z Turb'n Tag methodology which allows fish to be entrained through a specific passage route and be recaptured downstream.

Study sites

We've utilized the HI-Z tag technology to estimate the direct survival and injury rates of American and European Eel at seven propeller turbines and five Francis turbines at the following hydroelectric stations:

- Beaucaire on the Rhone River (France)
- Fessenheim and Ottmarshiem on the Rhine River (France)
- Robert-Moses on the St. Lawrence River
- Wilder, Vernon, Bellows Falls, and Turners Falls (Cabot Station and Station Number 1) on the Connecticut River

Propeller turbine characteristics

Station	Turbine Type	Number of blades	Runner speed (rpm)	Runner diameter (m)
Beaucaire	Bulb	4	94	6.24
Fessenheim	Kaplan	4	88.2	6.67
Ottmarsheim	Kaplan	5	93.75	6.25
Robert Moses Station	Propeller	6	99.2	6.10
Wilder	Kaplan	5	112.5	4.57
Vernon (Unit 8 at 28.5 m^3/s)	Kaplan	5	144	3.10
Vernon (Unit 8 at 48.4 m^3/s)	Kaplan	5	144	3.10

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Francis turbine characteristics

Station	Number of buckets	Runner speed (rpm)	Runner diameter (m)
Bellows Falls	15	85.7	4.42
Cabot Station	13	97.3	3.45
Station No. 1	13	200	1.37
Vernon (Unit 4)	13	133	1.59
Vernon (Unit 9)	12	75	2.79

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Methods

Source and maintenance of Eels

- Eels for each study were obtained from commercial fishermen.
- Eels were transported to the site before the start of the study and held in ~5,000 liter pools located near the headworks of the facility.
- A continuous supply of ambient river water was maintained in the pools and the eels were held for 12-24 hours prior to tagging and release to allow the fish to recover from the initial capture, transport, and handling stress.

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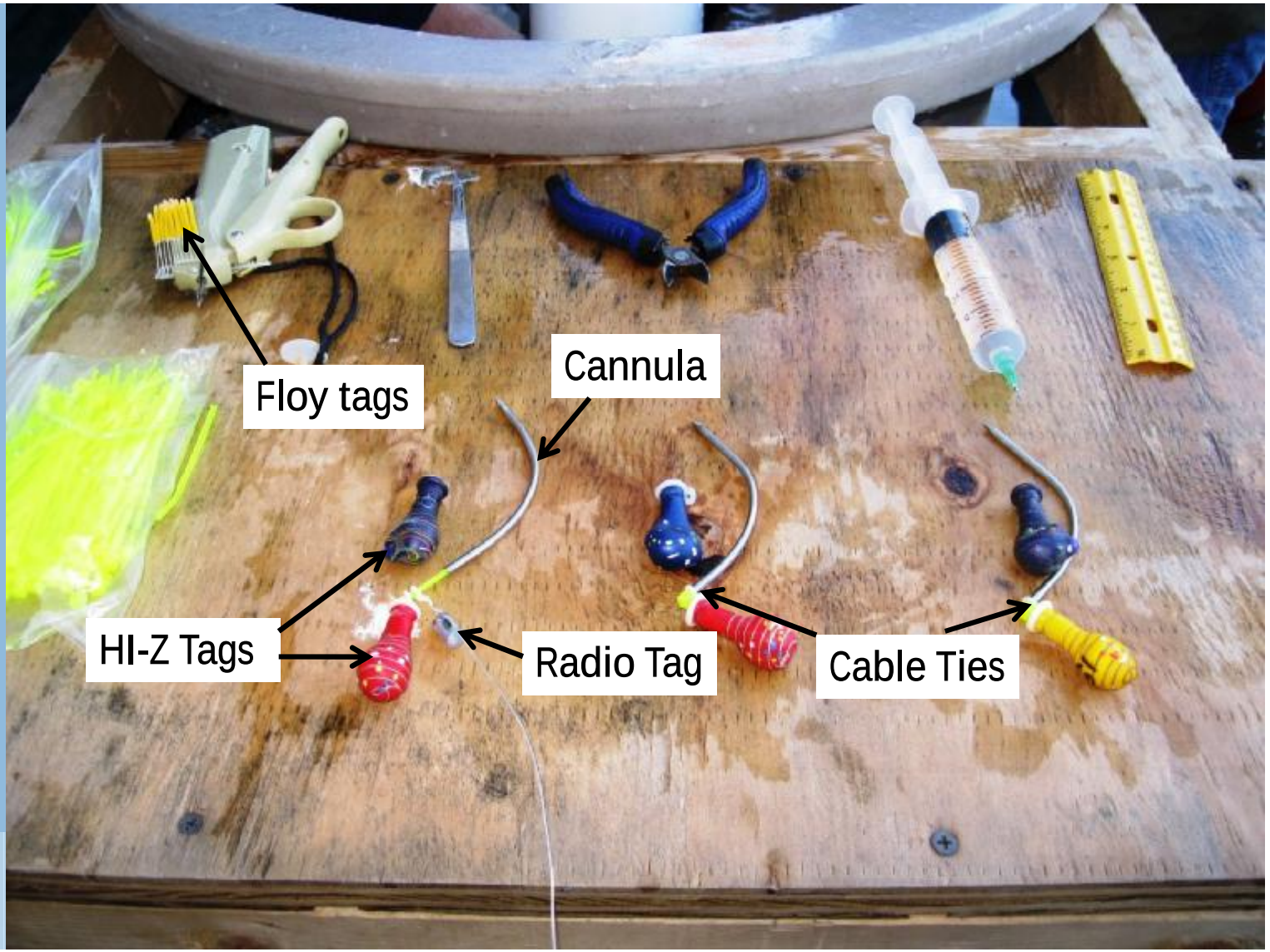

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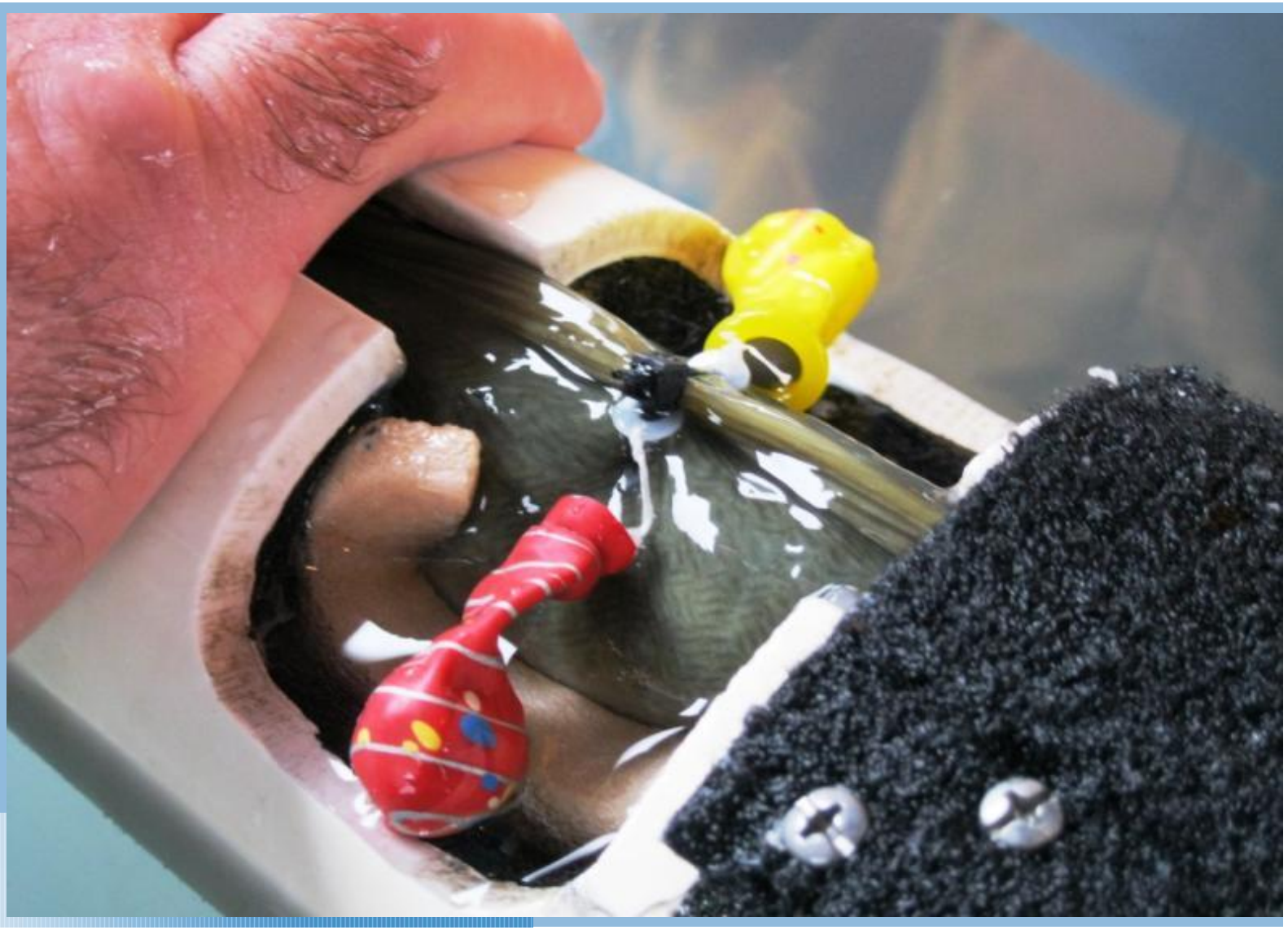

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Post-passage evaluations at each study:

- Survival: 1 hour and 48 hour
- Injury (presence/absence)
  - Types of injury (e.g. cut/scrape, bruise, severance, hemorrhaged eye)
    - Major or minor injury
  - Cause of injury (mechanical, shear, or pressure-related)

Results/Discussion

48 Hour Survival for Eels
Propeller – Mean = 80.7%
Francis – Mean = 95.1%

48 Hour Survival for all other species
Propeller – Mean = 92.1% (N = 218)
Francis – Mean = 83.2% (N = 33)

Station	Average length (mm)	48 h survival (%)
Propeller Turbines		
Beaucaire	686	93.0 ±1.5
Fessenheim	704	92.4 ±2.2
Ottmarsheim	750	78.6 ±2.3
Robert Moses Station	1020	73.5 ±3.4
Wilder	820.7	66.0 ±6.9
Vernon (Unit 8 at 28.5 m^3/s)	813	87.5 ±4.8
Vernon (Unit 8 at 48.4 m^3/s)	795	74.0 ±6.2
Francis Turbines		
Bellows Falls	816	98.0 ±2.0
Cabot Station	683	96.0 ±2.8
Station No. 1	636	90.0 ±5.5
Vernon (Unit 4)	818	93.5 ±3.6
Vernon (Unit 9)	796	97.9 ±2.1

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Mean Visible Injury Rate:
Propeller = 25.7%
Francis = 12.5%

Station	Number examined	Visible injury rate (%)*	Major injury rate (%)
Propeller turbines			
Beaucaire	263	7.2	6.5
Fessenheim	270	11.5	6.7
Ottmarsheim	294	26.5	20.7
Robert Moses Station	207	36.7	29.5
Wilder	47	42.6	36.2
Vernon (Unit 8 at 28.5 m^3/s)	46	28.3	8.7
Vernon (Unit 8 at 48.4 m^3/s)	44	27.3	22.7
Francis turbines			
Bellows Falls	50	14.0	6.0
Cabot Station	49	4.1	4.1
Station No. 1	26	0.0	0.0
Vernon (Unit 4)	45	35.6	20.0
Vernon (Unit 9)	46	8.7	0.0

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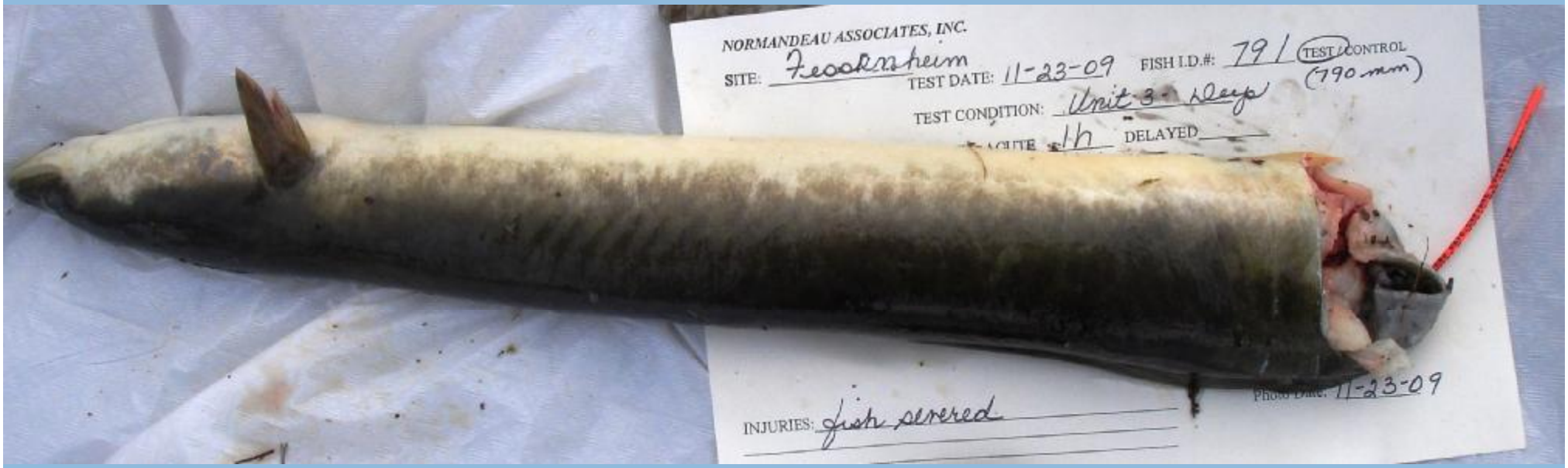

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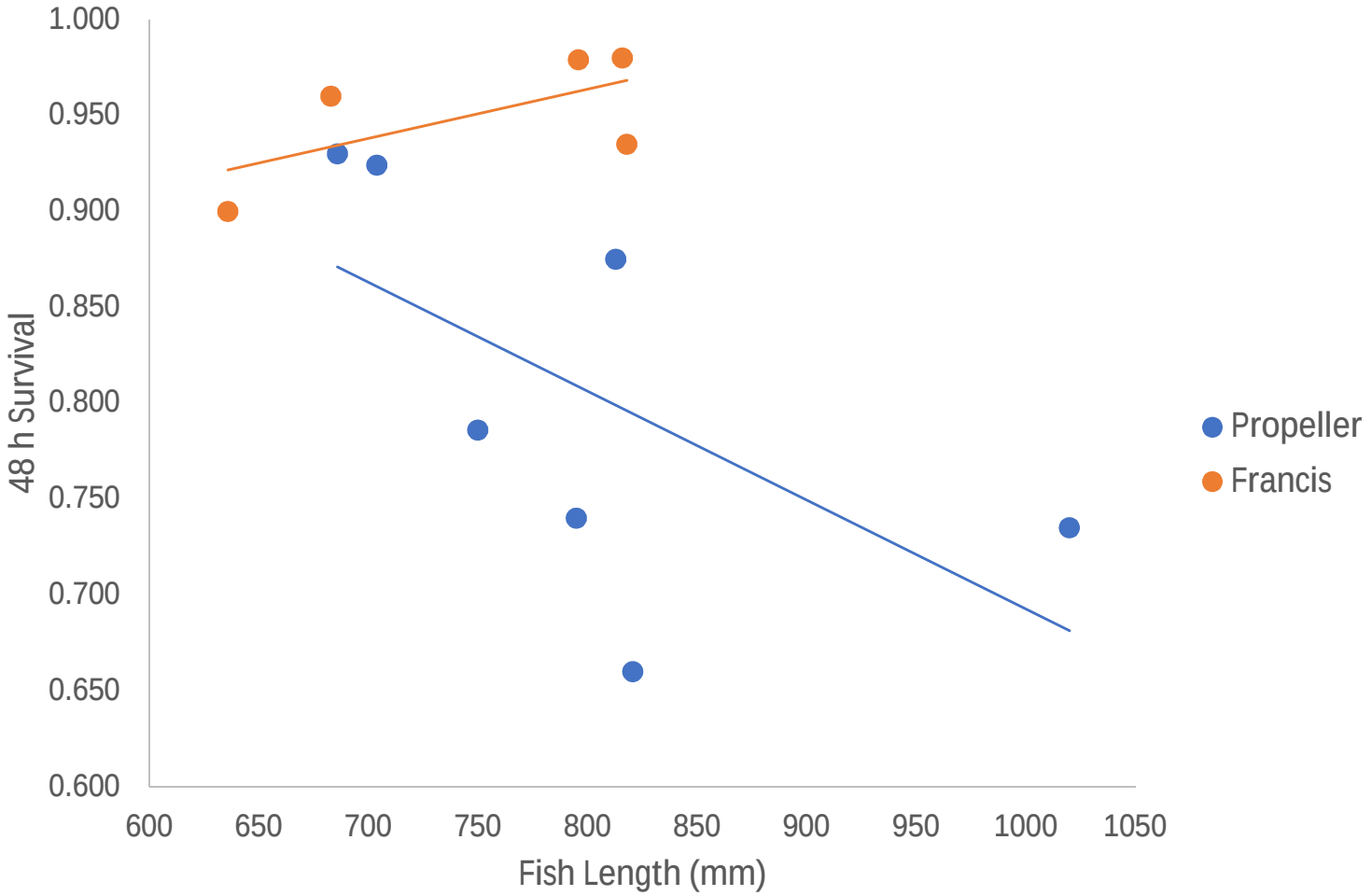
Survival vs. turbine characteristics/eel length

- The number of blades, runner speed, and runner diameter of a turbine, as well as eel length, seem to affect the survival estimates for eels passed through both types of turbine



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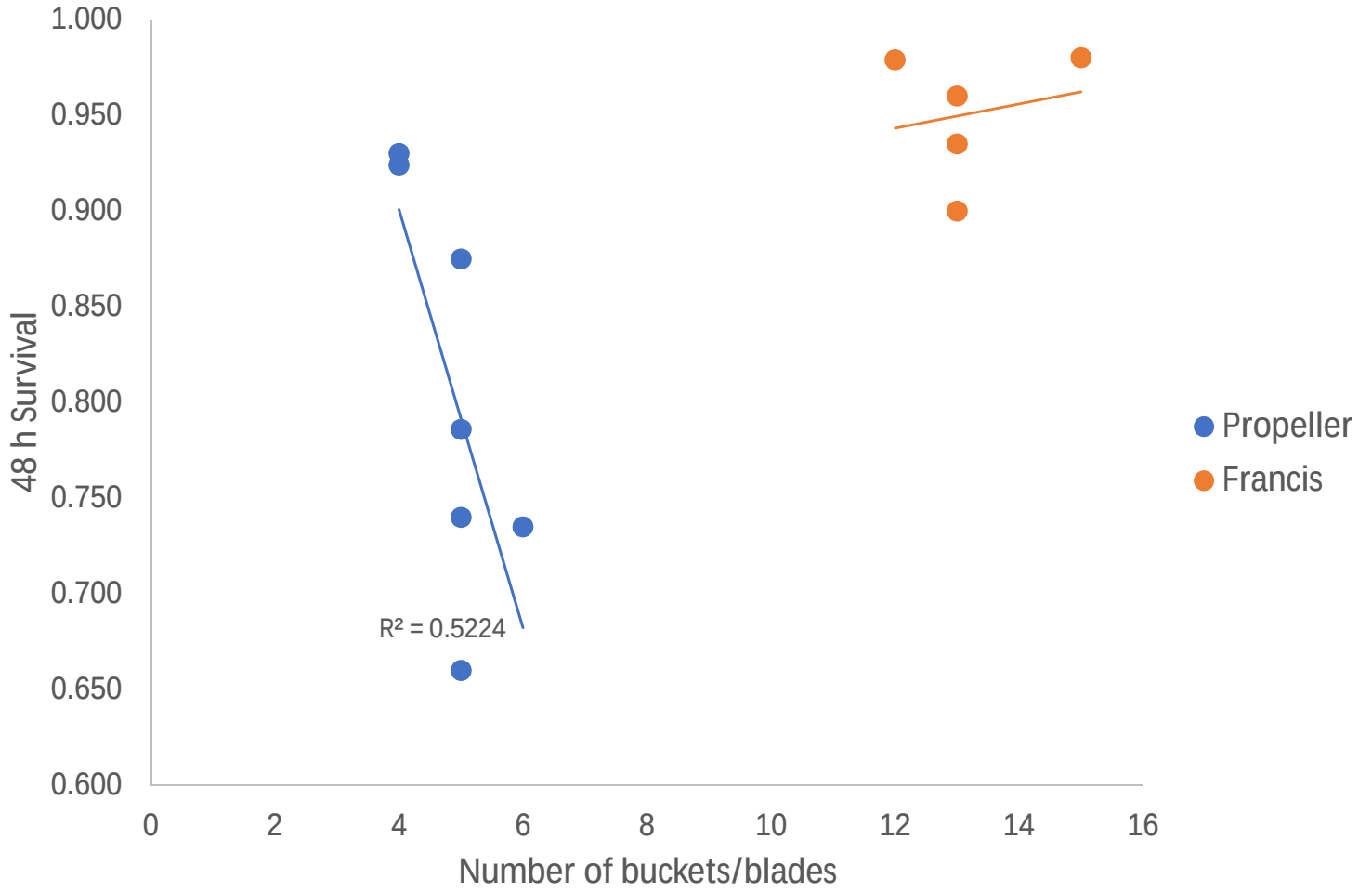

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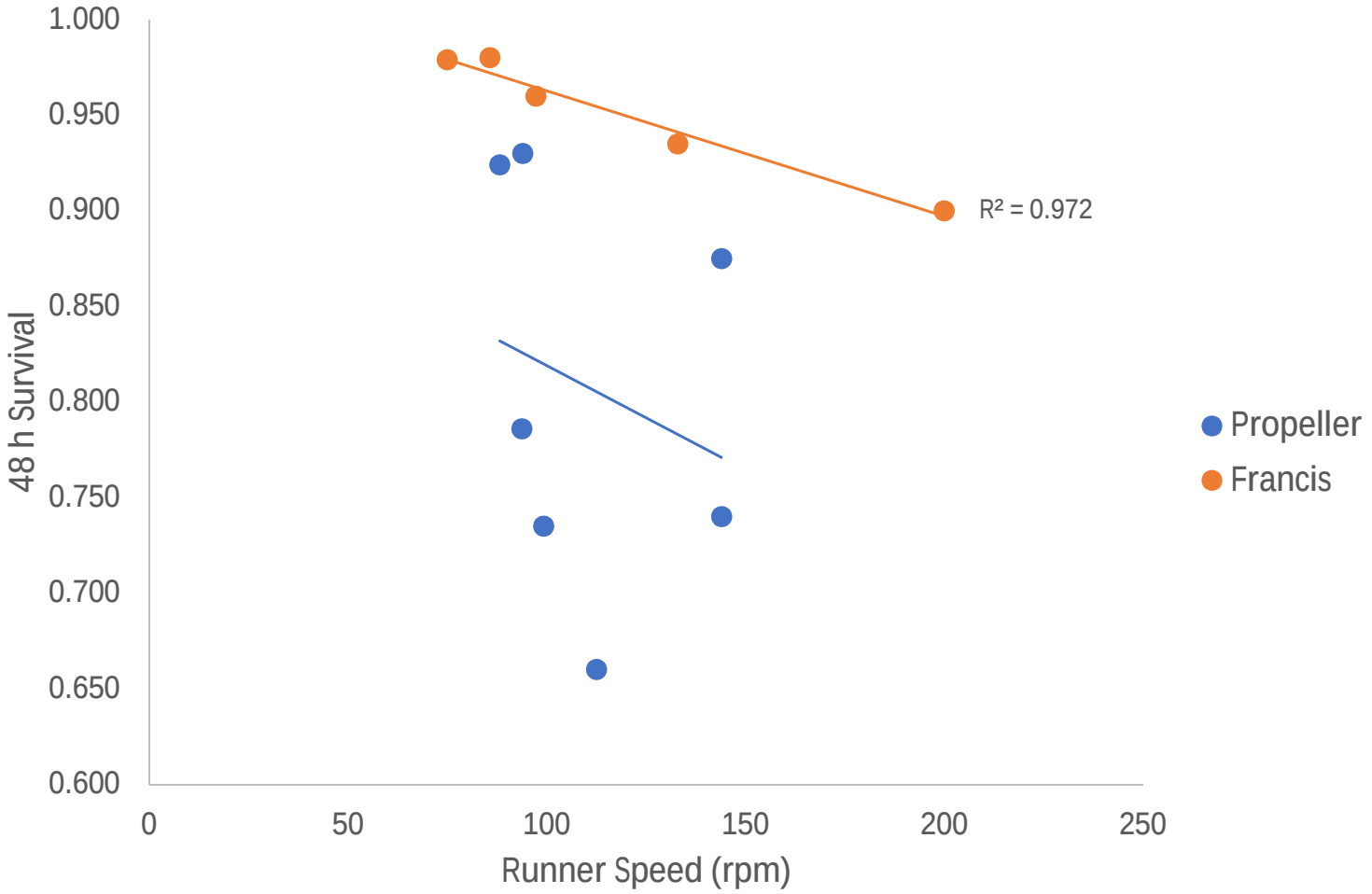

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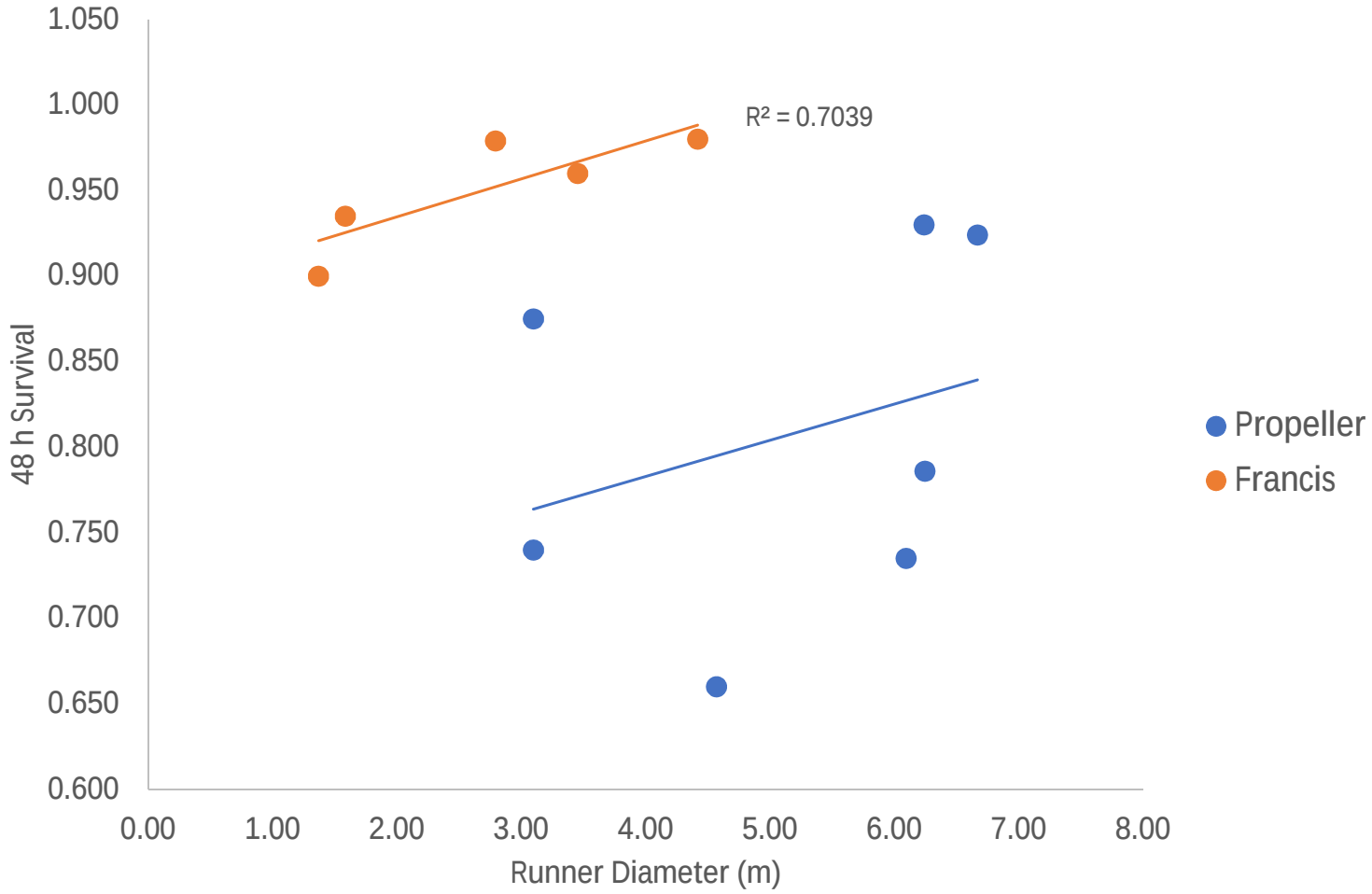

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Summary

- Survival and injury rates for most species of fish passing through Francis turbines is lower than those passed through propeller turbines.
- For eels, the opposite is true. Although the number of structural components of Francis turbines is greater, survival of eels was higher and less variable (90.0-98.0%).
- This difference may be due to the behavior of eels as they enter the turbine. Are they able to “wrap” around the rounded buckets of Francis turbines (which may only result in bruising)? It may also be related to the sharpness of the leading edge of propeller turbine blades, or some other unknown factor.